MEMORANDUM REPORT ARLCD-MR-78006

PROJECTILE INTERIOR COATING FOR COMPOSITION B IMPROVEMENT

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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ERRATA

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A system for coating a projectile interior to provide corrosion protection for the steel and to bond the TNT-based explosive casting to the projectile has been developed. The coating material, which consists of an adhesion promoter combined with a polyurethane, has shown excellent properties in laboratory tests at low, ambient, and high temperatures. The coating is a 50/50 mixture of Estane 5715/VMCH with 1% Epon 828 dissolved in a 50/50 methyl ethyl ketone/methyl isobutyl ketone solution to give a 20% concentration. The coating material is being

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tested on a pilot plant scale and has been effective in several loading tests performed to date. This coating appears to be sprayable with standard commercial spraying equipment.

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FIGURE

DISCUSSION

In this program, approximately one hundred adhesive-coating materials were evaluated for corrosion protection of steel and for use in bonding TNT-based explosives to the interiors of projectiles. Hot melts and acrylics (with and without plasticizers) were investigated, but they did not meet the requirements of the projectile adhesive-coating (see tables 1 and 2).

A United Kingdom (UK) technology which uses a paint solution was investigated as a standard for comparison. Since the paint is not readily available in this country, several paints produced in the US similar to the UK sample were ordered and evaluated. These materials were also unsatisfactory (table 2).

Polyurethane polymers supplied by Hooker Chemical, B.F. Goodrich, and Thiokol Chemical were evaluated. Initially, the aliphatic polyurethanes, aromatic-polyester polyurethanes, and polyether polyurethanes supplied were unsatisfactory. The bonds formed with zinc phosphated steel were marginal at best. Adding adhesion promoters to the polyurethanes increased the bond strengths to steel in several samples; however, only one of the polyurethanes, Estane 5715/VMCH, met the requirements of bonding to steel and reactivating at the melt temperature of Comp B to form a strong bond at the coating/Comp B interface. The slight solubility of Estane 5715 in TNT enhanced bonding. When Estane 5715 (B.F. Goodrich) and VMCH (Union Carbide Corp.) were combined in a concentration of 50/50 parts by weight (pbw) by dissolving them in ketone solvents, the resulting adhesive-coating had superior properties to the UK coating material (table 3). The combination of Estane 5715/VMCH works in almost all concentrations of from 5-95 pbw. However, the 50-50 concentration was found to give the best overall results for coating, bonding, and ease of application by spraying.

Tensile strength tests at low (-40°C), ambient (24°C), and high (63°C) temperatures and split-shell tests indicate that this coating meets all the requirements of the program. The vacuum stability test at 100°C gave the following results:

	Gas evolved (ml)
1. Comp B with 0.61 MNT + 0.5% Estane 5702	0.21
2. Estane 5715/VMCH with 1% Epon 828	0.78
3. Combination of 1 and 2, above	0.93

At present there is a problem in spray coating with the available equipment. Coating the interior of a 105-mm projectile using 10, 15, and 20% pbw solids in solvent (50/50 pbw of Estane 5715-VMCH in a 50/50 pbw of methyl ethyl ketone/methyl isobutyl ketone solvent) has not been entirely satisfactory. Satisfactory spray coatings can be achieved by using the proper spray equipment or manipulating the concentration of solvents (methyl ethyl ketone/methyl isobutyl ketone). There is also a possibility of using 2-pentanone, 3-pentanone, or 2-methyl 3-butanone, all of which have higher boiling points than methyl ethyl ketone and lower boiling points than methyl isobutyl ketone. The use of 2-pentanone, 3-pentanone or 2-methyl 3-pentanone depends on their availability in bulk quantities.

EXPERIMENTAL PROCEDURE

Tensile Strength of Adhesive-Coating Materials

Adhesive-coating materials were evaluated by coating a 1.27 x 2.54 cm (1/2 x 1 in.) area on each 2.54 x 7.62 cm (1 x 3 in.) aluminum coupon. Three samples of each adhesive-coating system were prepared and tested using a Baldwin Test Instrument. Using the tensile strength of Comp B neat as a standard [approximately 1.38 MPa(200 psi)], only samples exceeding this bond strength were tested.

Tensile Strength of Adhesive-Coating Materials with Comp B

The coating materials exceeding the 1.38 MPa (200 psi) tensile strength were further evaluated by placing them on 2.54 x 7.62 cm (1 x 3 in.) zinc phosphated steel coupons and shipping the coupons to the Energetic Materials Division. The coated coupons were heated to $80^{o} \pm 5^{o}C$, and a layer of Comp B was poured onto one coupon before the coupon was assembled to a second coupon (fig. 1). Three tensile shear-strength samples of each material were prepared and tested using an Instron Tensile Tester. Samples that met the requirements for adhesion at $24^{o}C$ ($75^{o}F$) were further tested at $-40^{o}C$ ($-40^{o}F$) and $63^{o}C$ ($145^{o}F$). A minimum 2.54×10^{-3} cm (0.001 in.) thick coating was necessary for successful bonding.

Formulation of Preferred Adhesive-Coating Materials

A 20% pbw solution of solids in solvent was prepared as follows:

260 g	methyl ethyl ketone	Certified Grade, Fisher Chemical Co.
260 g	methyl isobutyl ketone	Certified Grade, Fisher Chemical Co.
65 g	Estane 5715	B.F. Goodrich, Adhesive Prod. Div.
65 g	VMCH	Union Carbide Corp.
1.3 g	Epon 828	Shell Chemical Co. (Stabilizer)

Split-Shell Test

After brush coating 2.54×10^{-3} to 3.81×10^{-3} cm (1 to 1.5 mil) layers of adhesive on split shells, the shells were loaded with Comp B containing 0.5% Estane 5702 and 0.6% mononitrotoluene (MNT). Brackets were attached to both halves of the shells and they were placed horizontally in a nest. A dead load of two tons was applied to the lower halves of the splits to rupture the bonds. The shells were removed from the nest and the location of the rupture determined. The acceptance criterion for this test was failure within the Comp B, not at the shell/adhesive interface.

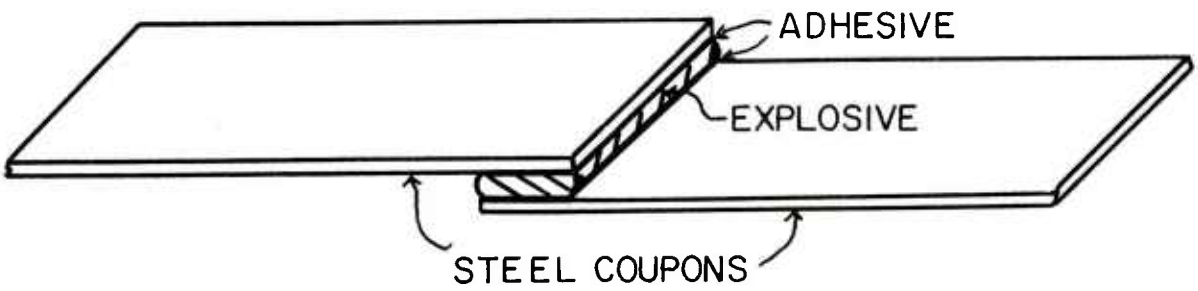

Figure 1. Coupon assembly for tensile test.

Materials

Modified Comp B - 60/40 RDX/TNT containing 0.5% Estane 5702 plasticized with 0.6% MNT.

Estane 5715 - a heat reactive aromatic-polyester polyurethane obtained from B.F. Goodrich.

VMCH - a copolymer of vinyl chloride (86%), vinyl acetate (13%) and inter-polymerized dibasic acid (1%), obtained from Union Carbide Corp.

Methyl ethyl ketone and methyl isobutyl ketone - certified grades obtained from Fisher Scientific Co.

Epon 828 - an epoxidized bisphenol A supplied by Shell Chemical Co.

CONCLUSION

Evaluation of Estane 5715-VMCH 50-50 pbw, the preferred adhesive/coating formulation, shows it to be superior in desirable properties to the adhesive/coating system used by the United Kingdom to reduce prematures under setback conditions.

Table 1

Tensile strength of adhesive coatings

Adhesive	Supplier	Bond strength 21°C (70°F) MPa	(psi)
Elastomer 4693	3M	0.8, 1.1	(120, 160)
Elastomer 34	3M	<0.7	(<100)
Foam 4400	3M	<0.7	(<100)
Elastomer 1870	3M	<0.7	(<100)
EVA/Acrylic Acid 3765	3M		---
Elastomer 4713	3M	0.9	(130)
Polyster A 1410B	Goodrich	<0.7	100
A 1453B	Goodrich		---
Hot Melt B4069	H.B. Fuller	1.0	(140)
Hot Melt L5056	H.B. Fuller	0.8, 0.8	(120, 110)
Amsco 112	Union Oil Co.	1.7, 1.1	(250, 160)
Amsco 114	Union Oil Co.	1.1, 1.3	(160, 190)
Amsco 115	Union Oil Co.	1.2, 1.0	(180, 150)
Amsco 125	Union Oil Co.	1.0, 1.5	(140, 220)
Amsco 319	Union Oil Co.	0.7, 1.0	(100, 140)
Hot Grip	Adhesive Products Corp.	1.1, 1.1	(160, 160)
Acrylic C 10CV	Rohm & Haas	8.3, 9.6	(1200, 1400)
Acrylic F10	Rohm & Haas	1.3, 2.8	190, 400
Hot Melt 3134	National Adhesives Co.	2.8	400
Hycar 2100X22	Goodrich	<0.7	(<100)
Hycar CTBN 1300X8	Goodrich	<0.7	(<100)
Eastobond A-167S	Eastman Chem Co.	<0.7	(<100)

Table 1 - Continued

Adhesive	Supplier	Bond strength 21°C (70°F) MPa	psi
Eastobond A-41	Eastman Chem. Co.	3.7	(530)
Super Beckacite 2100	Reichhold Chem. Co.	<0.7	(< 100)
PVA Emulsion	Borden Chemical	<0.7	(< 100)
Bostik GGP 1910	USM Corp.	<0.7	(< 100)
Piccolostic A-75	Penn. Ind. Chem.	<0.7	(< 100)
Hydrogum 300	Reichhold Chem. Co.	<0.7	(< 100)
VMCA	UCC	<0.7	(< 100)
Piccodeine 6215	Penn. Ind. Chem.	<0.7	(< 100)
Gantrez AN 137	GAF	<0.7	(< 100)
Kraton 1107	Shell Chem. Co.	<0.7	(< 100)
Kraton 1101	Shell Chem. Co.	<0.7	(< 100)
Eastobond A-41-Cumar R-7 (1/1 pbw)	Eastman Chem. Co. Neville Chem. Co.	<0.7	(< 100)
Eastobond A-41-MVE (1/1 pbw)*	GAF Eastman Chem. Co.	<0.7	(< 100)
MVE-Super Beckacite 2100 (1/1 pbw)	GAF Reichhold Chem. Co.	<0.7	(< 100)
Piccolostic A-75-Cumar R-7 (1/1 pbw)	Penn. Ind. Chem. Neville Chem. Co.	<0.7	(< 100)
Eastobond M-5W-Zonerez B115 (1/1 pbw)	Eastman Chem. Co. Arizona Chem. Co.	2.8	(400)
Eastobond A-41-Zonester B85 (2/1 pbw)	Eastman Chem. Co. Arizona Chem. Co.	2.8	(400)

Table 1 - Continued

Adhesive	Supplier	Bond strength 21°C (70°F) MPa	psi
Kraton 1107 - S.P. 1068 (2/1 pbw)	Shell Chem. Co. Schenectady Chem.	<0.7	(<100)
Kraton 1107-CRJ 683 (2/1 pbw)	Shell Chem. Co. Schenectady Chem.	<0.7	(<100)
Eastobond A-1675-Zonerez B115 (3/1 pbw)	Eastman Chem. Co. Arizona Chem. Co.	<0.7	(<100)
Eastobond A-41- Zonester B85 (3/1 pbw)	Eastman Chem. Co. Arizona Chem. Co.	<0.7	(<100)
Eastobond M-5W-Piccotex 100 (4/1 pbw)	Eastman Chem. Co. Penn. Ind. Co.	<0.7	(<100)
Eastobond A-41-Piccotex 100 (4/1 pbw)	Eastman Chem. Co. Penn. Ind. Co.	2.4	(350)
Eastobond A-41-XYHL (4/1 pbw)	Eastman Chem. Co. U.C.C.	1.7	(250)
Bostik 6590, Cat #213	U.S.M. Corp.	1.0	(150)
Bostik 6590, Cat #27002	U.S.M. Corp.	1.0	(150)
Estane 5702	Goodrich	LO+2	(35)
Estane 58630	Goodrich	No Bond	
Estane 58300	Goodrich	No Bond	
Bostik 6590-Piccotex 75 (4/1 pbw)	V.S.M. Corp Penn. Ind. Chem.	1.9	(275)
Eastobond A-41-Easto-bond A-167S (4/1 pbw)	Eastman Chem. Co.	1.0	(285)
Eastobond A-41-Piccotex 75 (4/1 pbw)	Eastman Chem. Co. Penn. Ind. Chem.	2.1	(300)

Table 1 - Continued

Adhesive	Supplier	Bond strength 21°C (70°F) MPa	psi
Bostik 6323	U.S.M. Corp.	2.1	(300)
Bostik 6363	U.S.M. Corp.	1.1	(160)
Eastobond A-41-Amsco 125 (3/1 pbw)	Eastman Chem. Co. Union Oil of California	3.4	(500)
Hot Melt 8096	Coronet Paper Co.	0.8	(110)
Versalon 1300	General Mills	4.6	(670)
Versamide 872	General Mills	1.6	(230)
Eastobond A-41-Piccotex 75 (3/1 pbw)	Eastman Chem. Co. Penn. Ind. Co.	1.3	(190)
Eastobond A-41-Amsco 125 (3/1 pbw)	Eastman Chem. Co. Union Oil of California	3.4	(500)

Table 2

Tensile strength of adhesive coating with Comp B

Adhesive	Bond strength 21°C (70°F) MPa	(psi)	Bond failure
Estane 5702 w/7% TNT	0.7	(100)	Adhesive to metal failure
Thermogrip 6590 Piccotex 75 (4/1 pbw)	1.5	(220)	40% adhesive-adhesive bonding
A41/167 S (4/1 pbw)	0.9	(130)	(1) 40% adhesive failure (2) 70% adhesive-adhesive bonding
A41/Piccotex 75 (4/1 pbw)	1.4	(205)	(1) 20% adhesive-failure (2) 80% adhesive-adhesive bonding
3M Hot Melt	1.1	(165)	30% adhesive failure
Bostik 6323	1.4	(200)	(1) 20% adhesive-adhesive bonding (2) Composition B failure
	0.5	(75)	Adhesive to Composition B failure
A-41	--	---	Adhesive to Composition B failure
4713	0.4	(60)	Adhesive to Composition B failure
1870	0.2	(35)	Adhesive to Composition B failure

Table 2 - Continued

Adhesive	Bond strength 21°C (70°F) MPa	(psi)	Bond failure
B 4069	0.3	(50)	Adhesive to Composition B failure
L 5056	0.6	(80)	Composition B cracked Adhesive extremely elastic
Hot Grip	0.5	(70)	Adhesive to Composition B failure
AMSCO 1.2	0.2	(25)	Adhesive to Composition B failure
Kew-Lux Acrylic Paint	0.7	(100)	Adhesive failure
Ferrothane Polyurethane Paint	0.8	(110)	Adhesive failure
U.K. Paint	1.1	(165)	10/90 Composition B/ adhesive failure
U.K. Paint Solution	1.3	(190)	50/50 Composition B/ adhesive failure
U.K. Paint	0.1 (63°C,	(19) 145°F)	Adhesive failure
90/10 pbw Estane 5702/Poly Vinyl Acetate (PVA)	1.9	(275)	Composition B failure
90/10 pbw Estane 5702/PVA	0.2 (63°C,	(23) 145°F)	Adhesive failure
75/25 pbw Estane 5702/PVA	1.7	(240)	Composition B failure
75/25 pbw Estane 5702/PVA	0.5 (63°C,	(70) 145°F)	Adhesive failure

Table 2 - Continued

Adhesive	Bond strength 21°C (70°F) MPa	(psi)	Bond failure
1st Coat 75/25 pbw Estane 5702/PVA 2nd Coat 100 Estane 5702	0.8	(110)	Adhesive failure
75/25 pbw Estane 5702/VMCH with 40% TiO_2	1.4	(206)	90% Composition B failure
75/25 pbw Estane 5715/VMCH	1.5	(220)	75% Composition B failure
85/12 pbw Rohm & Haas C10LV/Monsanto Benzo flex S-432	1.6	(230)	Composition B failure
75/25 pbw Estane 5713/VMCH	1.1	(160)	50% Adhesive failure
75/25 pbw Estane 5714/VMCH	1.2	(175)	50% Adhesive failure
75/25 pbw Estane 5701 F1 VMCH	1.4	(205)	80% Composition B
75/25 pbw Estane 5702 F2/VMCH	1.2	(180)	80% Composition B failure
75/25 pbw Estane 5708 F1/VMCH	1.3	(190)	80% Composition B failure
75/25 pbw Estane 5710 F1/VMCH	1.4	(205)	85% Composition B failure
75/25 pbw Estane 5715/VMCH	1.5	(220)	75% Composition B failure
3/1 pbw Estane 5715/VMCH in MEK prepared 12/15/77	1.4	(210)	100% Composition B failure
3/1 pbw Estane 5715/VMCH in MEK	1.4	(200)	100% Composition B failure
1/1 pbw Estane 5715/VMCH in MEK	1.4	(210)	100% Composition B failure
3/1 pbw Estane 5715/VMCH in THF	1.4	(205)	100% Composition B failure
1/1 pbw Estane 5715/VMCH in THF	1.7	(240)	100% Composition B failure
3/1 pbw Estane 5715/VMCH in MEK w/1% propylene oxide added	1.6	(225)	100% Composition B failure
1/1 pbw Estane 5715/VMCH (B590) in THF	1.4	(205)	100% Composition B failure

Table 2 - Continued

Adhesive	Bond strength 21°C (70°F) MPa	(psi)	Bond failure
3/1 pbw Estane 5715/VMCH (B590) in THF	1.1	(160)	Adhesive was not cured properly prior to heating in oven and bubbled.

Table 3

Tensile strength of selected adhesive coating with Comp B*

	Bond strength @ various temperatures						
	70°F		-40°F		145°F		
Adhesive	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	Remarks
75/25 Estane 5715/VMCH	1.5	220	1.3	186	0.9	133	100% Comp B failure
50/50 Estane 5715/VMCH w/1% Propylene Oxide	2.5	359	2.5	362	1.3	183	100% Comp B failure
50/50 Estane 5715/VMCH w/1% Epon 828	2.7	385	--	--	--	--	100% Comp B failure
U.K. Paint Solution	1.3	190	--	--	0.02	26	Internal adhesive failure @ 145°F

*Note: Comp B contained 0.5% Estane 5702, 0.6% MNT.

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